Clear Creek Gambusia
Gambusia heterochir

5-Year Review
Summary and Evaluation

U.S. Fish and Wildlife Service
Austin Ecological Services Field Office
Austin, Texas

Cover photos:

Top: Clear Creek gambusia female (by TPWD, Campbell 2003).

Bottom: Wilkinson Spring, upper spring pool at Clear Creek, “upper dam” is in the upper right of the photo (by USFWS).

5-YEAR REVIEW

Species reviewed: Clear Creek Gambusia, *Gambusia heterochir*

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Clear Creek Gambusia (*Gambusia heterochir*)

1.0 GENERAL INFORMATION

1.1 Reviewers

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Cooperating Regional Office(s): N/A

1.2 Methodology Used to Complete the Review

The U.S. Fish and Wildlife Service (USFWS) conducts status reviews for species on the List of Endangered and Threatened Wildlife and Plants List (50 CFR 17.12) as required by section 4(c)(2)(A) of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.) (Act). Public notice for this review was published in the Federal Register on March 20, 2008 (73 FR 14995). This review was conducted by Austin Ecological Services Field Office (AESFO) staff using information from the 1982 Clear Creek Gambusia Recovery Plan (USFWS 1982), peer-reviewed articles, agency reports, and other documents available in the AESFO files.

1.3 Background

The purpose of this 5-year review is to ensure that the Clear Creek gambusia has the appropriate level of protection under the Act. The review documents a determination by the USFWS whether its status has changed since the time of its listing. The review also provides updated information on the current threats to the species, ongoing conservation efforts, and the priority needs for future conservation actions.

The Clear Creek gambusia (*Gambusia heterochir* Hubbs 1957) is a small fish in the family Poeciliidae that bears its young live and has an extremely restricted range in west-central Texas. Campbell (2003, pp. 1-2) and Hubbs et al. (2002, p. 422) provide summary overviews of the Clear Creek gambusia. Its entire natural range is limited to one small spring-fed stream and the current range is limited to a small impounded spring head, encompassing an area of about 0.35 acres (1,400 square meters). It has been of conservation concern since its discovery in 1953 and its Federal protection predates the current (1973) Act.

The original listing of the Clear Creek gambusia was under the Endangered Species Preservation Act of 1966 (80 Stat. 926; 16 U.S.C. 668aa(c)). Clear Creek gambusia was listed by the State of Texas in 1973 (USFWS 1982, p. 1). The American Fisheries Society's Endangered Species Committee lists the Clear Creek gambusia as endangered due to hybridization, competition, and a narrowly restricted range (Jelks et al. 2008, pp. 387, 402). The Southeast Fishes Council also categorized the species as endangered (Warren et al. 2000, p. 26), and Nature Serve designates its status as G1, critically imperiled (www.natureserve.org, December 2009).

A recovery plan was prepared for the Clear Creek gambusia by the Rio Grande Fishes Recovery Team in 1980 and approved by the USFWS in 1982 (USFWS 1982). There have been no section 7 consultations or section 10 Habitat Conservation Plans. Because it was added to the list of protected species prior to the Act, the status of the fish was not previously analyzed using the five listing factors (32 FR 4001). As a result, this 5-year review represents the first complete analysis of the threats to the species based on the five listing factors.

1.3.1 FR Notice citation announcing initiation of this review:
March 20, 2008 (73 FR 14996), 90-day request for information period closed June 18, 2008. No comments were received.

1.3.2 Listing history:
Original Listing
FR notice: 32 FR 4001
Date listed: March 11, 1967
Entity listed: Species, *Gambusia heterochir*
Classification: Endangered
This was the original listing of the Clear Creek gambusia under the Endangered Species Preservation Act of 1966. The species is now listed under the Act. No critical habitat has been designated.

Revised Listing, if applicable
FR notice: N/A
Date listed:
Entity listed:
Classification:

1.3.3 Associated rulemakings: None.

1.3.4 Review History:
A 5-year review was initiated on July 22, 1985 (50 FR 29901) for all species listed before 1976 and in 1979-1980; a notice of completion with no change in status was published on July 7, 1987 (52 FR 25522). Another 5-year review was initiated on November 6, 1991 (56 FR 56882) for all species listed before 1991, but no document was prepared for this species.

1.3.5 Species' Recovery Priority Number at the start of this 5-year review:
The Recovery Priority Number at the start of this 5-year review was 2, meaning a high degree of threat, the recovery potential is high, and the listed entity is a species.

1.3.6 Current Recovery Plan or Outline
Name of plan or outline: Clear Creek Gambusia Recovery Plan
Date issued: January 14, 1982
Dates of previous revisions, if applicable: N/A

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate?
__X__ ***Yes***
_____***No***

2.1.2 Is the species under review listed as a DPS?
____ ***Yes***
__X__ ***No***

2.1.3 Was the DPS listed prior to 1996? N/A

2.1.3.1 Prior to this 5-year review, was the DPS classification reviewed to ensure it meets the 1996 policy standards? N/A

2.1.3.2 Does the DPS listing meet the discreteness and significance elements of the 1996 DPS policy? N/A

2.1.4 Is there relevant new information for this species regarding the application of the DPS policy?
____ ***Yes***
__X__ ***No***

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan?

_X_ ***Yes***
____ ***No***

1.2.1.1 Does the recovery plan containing objective, measurable criteria?

____ ***Yes***
_X_ ***No*** [recovery plan does not have criteria (USFWS 1982, p. 9)]

2.2.2 Adequacy of recovery criteria.

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat? N/A

____ ***Yes***
____ ***No***

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria? N/A

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:
The 1982 Clear Creek Gambusia Recovery Plan does not list delisting or downlisting criteria. The goal of the plan is to "secure survival" of the Clear Creek gambusia. "As the plan is implemented, the Fish and Wildlife Service… will recommend appropriate reclassification." The plan states that because of the extremely limited distribution, it may never be delisted completely (USFWS 1982, p. 9).

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat:

2.3.1.1 New information on the species' biology and life history:
Summaries of biological information on Clear Creek gambusia can be found in USFWS (1982, pp. 2-4), Edwards (1999, pp. 51-53), and Hubbs et al. (2002, p. 422).

Clear creek gambusia are viviparous (meaning they bear live young, rather than laying eggs). The reproductive season for Clear Creek gambusia is February to October with highest fecundity occurring in June to August (Hubbs 1971, pp. 32, 34). Like all *Gambusi*a, males have modified anal fins called gonopodia used for insemination during reproduction. Clear Creek gambusia have uniquely notched pectoral fins upon which the gonopodia is placed during copulation (transfer of sperm from male to female) (Hubbs and Reynolds 1957, p. 334; Wharburton et al. 1957, p. 299). Once a female is inseminated they can store sperm for several months so that males need not be present during much of the reproductive season and females can store sperm over the winter (Hubbs 1971, p. 34). Clear Creek gambusia is not known to migrate. They remain close to the outflow of spring openings throughout their life (Hubbs 1957, p. 8).

Clear Creek gambusia feed on small invertebrates, primarily the Clear Creek amphipod (*Hyalella texana*) (Hubbs 1971, p. 26). The amphipod is also endemic to Clear Creek and is found in association with coontail (*Ceratophyllum demersum*), an aquatic submerged plant abundant in Clear Creek gambusia habitat (Stevenson and Peden 1973, p. 434).

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

Clear Creek gambusia occurs in only one small, isolated population. No other populations have ever been known (Hubbs 1957, p. 8). In this one limited area of less than about 0.35 acre (ac) (1,400 square meters, m^2) (Figure 1C; USFWS 1982, p. 6a), upstream of a hand-built rock-earthen dam (described below), both Clear Creek gambusia and the common western mosquitofish, *G. affinis*, exist together and also sometimes form a hybrid swarm (described below). The western mosquitofish is a ubiquitous fish that occurs throughout much of the southeastern United States and all of Texas (Hubbs et al. 2008, p. 37). The total population trends and status of Clear Creek gambusia have not been documented, although Hubbs et al. (2002, p. 442) refers to “thousands” of Clear Creek gambusia in the one population. The health of the population has been monitored based on the relative abundance of the species compared to *Gambusia affinis* and the percent of pure fish in the upper head pool (described below).

The size at sexual maturity for females is 1 inch (in) (25 millimeters, mm) standard length (SL) (Hubbs 1971, p. 10), while the minimum maturation size of male fish is 0.7 in (17 mm) SL (Yan 1986, p. 1). Unlike other fish species in the Family Poeciliidae, male Clear Creek gambusias continue significant post-maturation growth in body size, though the rate of growth is significantly lower than that of females or young, immature males (Yan 1987, pp. 734, 738).

Fecundity varies from 1 to 28 with an average of 9 embryos per brood (young fish birthed at the same time). The interbrood interval varies from 48 to 70 days with an average of 61 days in lab conditions (Yan 1986, p. 1). Brood production is affected by light intensity with significantly fewer broods at lower light (Hubbs 1999, p. 748).

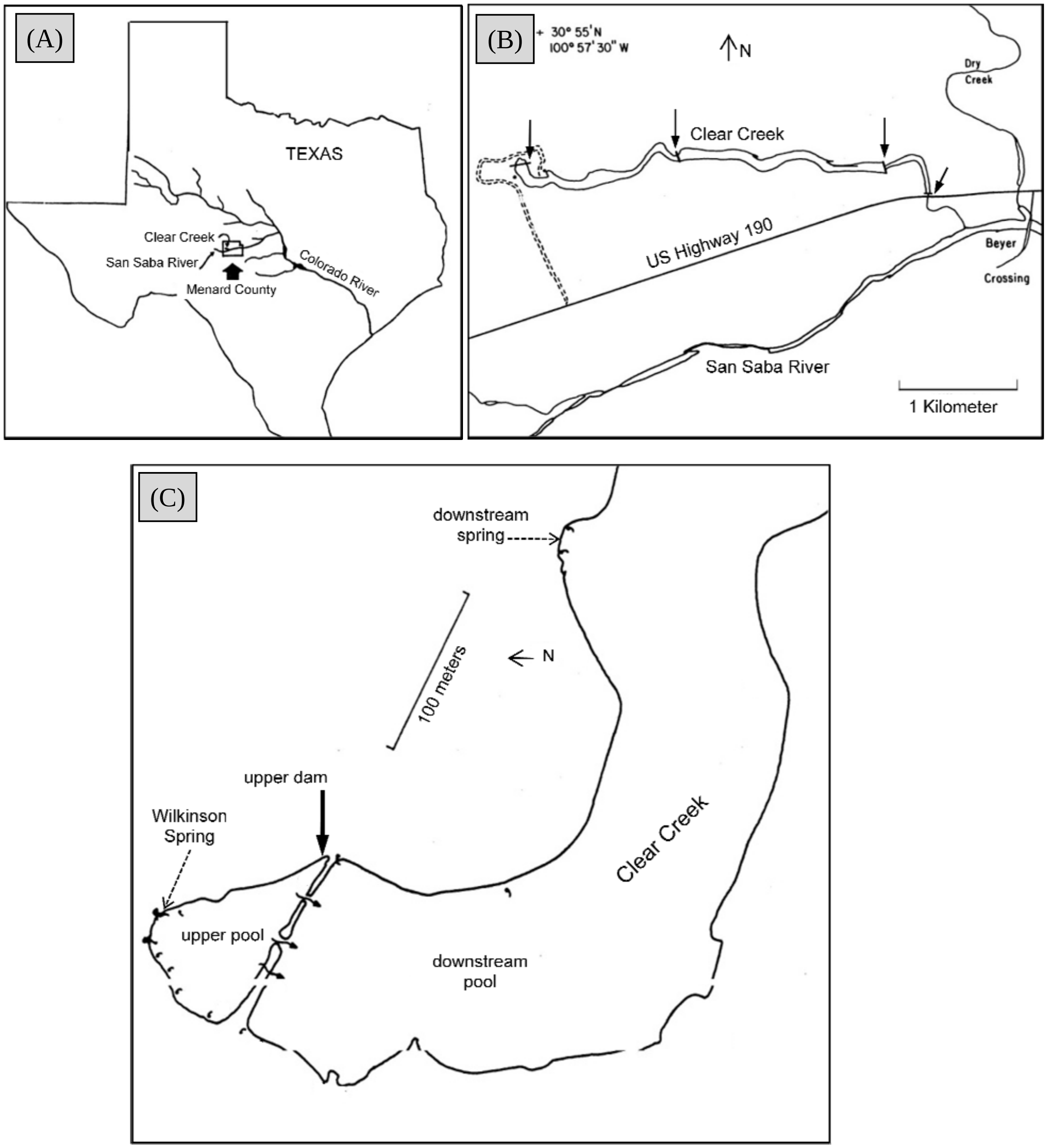

Figure 1. Clear Creek gambusia range maps (adapted from USFWS 1982, pp. 6a, 6b). Map A shows the location of Clear Creek within Menard County in the Colorado River basin of Texas. Map B shows the location of Clear Creek relative to the San Saba River (solid arrows point to dams). Map C shows the headwater area of Clear Creek (marks indicate locations of spring outflows).

Gambusia rarely live more than one year and may reach maturity as early as three months of age (Hubbs 1971, p. 14). Females commonly outnumber males by nearly two to one (Hubbs 1971, p. 10). The age structure of the population based on monthly sampling showed consistent distributions across seasons and years because there is level fecundity during the extended breeding season (nine months) and young fish grow relatively quick (Hubbs 1971, pp. 20, 25).

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):
Genetic studies of Clear Creek gambusia have focused on analyzing the extent of hybridization with western mosquitofish (Yardley and Hubbs 1976, p. 117; Davis et al. 2006, p. 351) or phylogeny (Lydeard et al. 1995, p. 223). Levels of hybridization have ranged from near 0 percent in 2003 samples (Davis et al. 2006, p. 351) to a high of 10 percent from the 1950s to the 1970s (Johnson and Hubbs 1989, p. 308) (see section 2.3.2.5 for more discussion of hybridization). No information has been published analyzing the intraspecific genetic diversity of the species.

2.3.1.4 Taxonomic classification or changes in nomenclature:
The Clear Creek gambusia was discovered in 1953 and formally described in 1957 by Dr. Clark Hubbs (Hubbs 1957, p. 5). Early phylogenetic studies of the species were based primarily on gonopodia (modified anal fin) structure, a diagnostic morphologic characteristic for the genus (Rivas 1963, p. 332). Clear Creek gambusia is in the subgenus *Arthrophallus*, and a member of the *nobilis* species group (species group is a taxonomic grouping of species below the subgenus level), while western mosquitofish is in the same subgenus, but in the *affinis* species group (Rauchenberger 1989, p. 3). The taxonomy and nomenclature of the Clear Creek gambusia has not changed or been questioned (Hubbs et al. 2008, p. 38) since its original description.

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):
The Clear Creek gambusia exists only in the spring fed headwaters of Clear Creek, a perennial tributary of the San Saba River in the Colorado River Basin of Menard County, Texas (Figure 1). The range of the Clear Creek gambusia has not changed since it was first discovered in 1953 (Hubbs 1957, p. 8; Edwards et al. 2004, pp. 257-258; Hubbs et al. 2008, p. 38). Though recent surveys have not been conducted and searches can be limited by access to private property, early fish surveys throughout the nearby area found it restricted to the one isolated spring system in Clear Creek in Menard County (Hubbs 1957, p. 8).

The fish is not found in downstream habitats due to increased temperature and pH fluctuations which favor the western mosquitofish (Hubbs 1959, p. 242; 2001, p. 321). Hubbs (1957, p. 8) speculated that Clear Creek gambusia may have once been more widely distributed in central Texas, but was outcompeted by western mosquitofish in other locations. At times, some individuals of Clear Creek gambusia have been found downstream of the headspring pool (Figure 1C) where other small springs enter the creek system (Edwards and Hubbs 1985, p. 14; Hubbs 2001, p. 317). These small spring areas are very restrictive in size and contain mostly western mosquitofish with no physical separation of the two species.

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):
The following summary discussion is adapted largely from Johnson and Hubbs (1989, pp. 307-309) and is based on field and laboratory studies by Hubbs (1971, pp. 1-47) and Edwards and Hubbs (1985, pp. 1-31).

The Clear Creek gambusia is restricted to headspring waters issuing from privately-owned land on Clear Creek in Menard County, Texas (Figure 1A). The main spring, Wilkinson Spring, is on a private ranch in a rural setting about 10 miles (mi) (16 kilometers, km) west of Menard. The population of Menard County is less than 2,500 people (TWDB 2006, Table 1.1-1, p. 1-3). The surrounding land on the ranch (oak/juniper woodlands of the Edwards Plateau) is managed for recreational hunting and low-density cattle grazing. One home (currently used as a recreational residence) is located about 650 ft (ft) (200 m) from the head spring on Clear Creek and a cabin is located about 30 ft (10 m) from the stream bank near a smaller spring opening downstream of the dam.

When the fish was discovered in 1953, Clear Creek had already been significantly altered by 4 dams approximately 330 ft, 1.1 mi, 2.2 mi, and 2.6 mi (100 m, 1.7 km, 3.6 km, and 4.2 km, respectively) downstream from the headsprings (Figure 1B). Clear Creek is only about 3.1 mi (5 km) long from its origin at Wilkinson Spring to the confluence with the San Saba River. The upstream most dam (hereafter, the upper dam) was constructed before 1900, the other three were built in the 1930s or later. Prior to 1930, Clear Creek was a cypress-lined stream with numerous large pools separated by short riffles. Due to the dams, the creek became a series of four pools approximately 300 ft (100 m) wide, with each impoundment backing up water to the base of the next dam upstream. Flow from Wilkinson Spring has varied from 6.2 to 31.8 cubic-feet per second (cfs) (0.18 to 0.90 cubic meters per second, cms) since 1902, depending upon aquifer recharge (Figure 2; Brune 1975, p. 55; U.S. Geological Survey, USGS 2009).

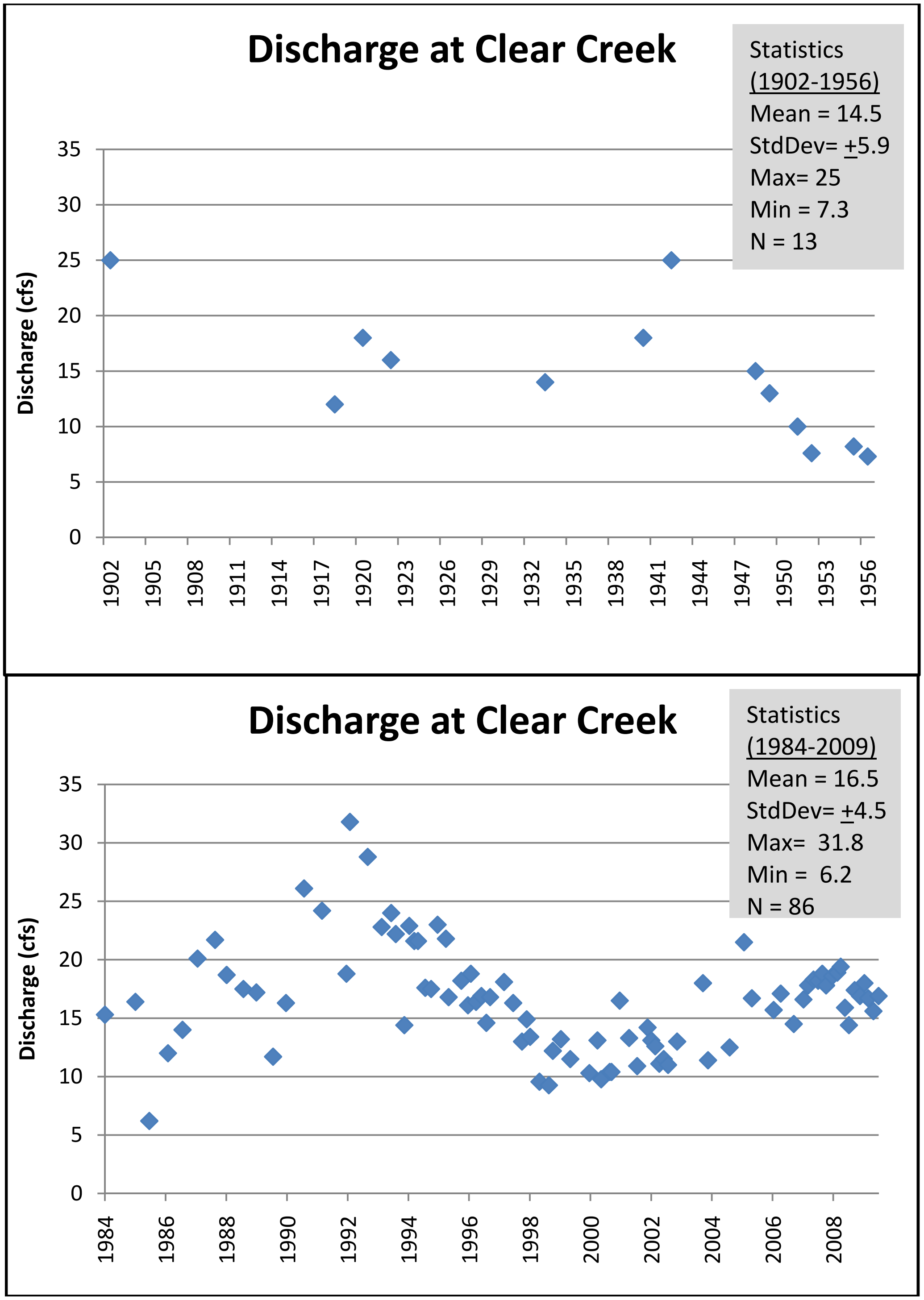

Figure 2. Measured stream flows (cubic-feet per second) and statistics for Clear Creek at the State Highway 190 bridge crossing from 1902 to 1956 (top: Brune 1975, p. 55) and 1984 to 2008 (bottom: U.S. Geological Survey 2009).

Clear Creek gambusias are spring-adapted and limited to the flowing, clear, stenothermal (constant temperature of about 20.8 ºC, 69.4 ºF), near neutral pH (7.1) waters of the spring outflow (Hubbs 2001, p. 311). As with other spring systems in Texas, Hubbs (1995, pp. 989-990; 2001, p. 321, 324) found that the low variation in water temperatures was the main factor separating spring-adapted fish (like Clear Creek gambusia) from stream-adapted fish (like western mosquitofish). There continues to be two somewhat distinct biotic assemblages and environmental conditions in Clear Creek. Upstream of the upper dam in the headspring pool, Clear Creek gambusia, an endemic amphipod (*Hyalella texana*), and the submerged plant *Ceratophyllum* sp. occur in the stenothermal (constant temperature), relatively nuetral pH waters of the spring outflow (Stevenson and Peden 1973, pp. 433-434). Downstream of the upper dam western mosquitofish, a common amphipod (*Hyalella azteca)*, and the submerged plant *Myriophyllum* sp. occur in the relatively eurythermal (varying temperatures) and higher pH waters. The submerged aquatic plants provide important protective cover for fish to avoid potential predators and it also provides substrate for the amphipods that are a primary food source for the fish. The endemic amphipod, *H. texana*, was found to dominate the diet of the Clear Creek gambusia (Hubbs 1971, p. 26).

Presumably, the free-running Clear Creek originally (before dams were built) had stenothermal headwaters and spring run, with more eurythermal waters further downstream. The interface between these habitat types was relatively wide, with a gradation between extremes. Impoundments by the 1930s brought the two habitat types in proximity and may have allowed the high frequency of hybridization between Clear Creek gambusia and western mosquitofish (Johnson and Hubbs 1989, p. 308). Regardless of duration and extent of hybridization, there is no evidence that the two gene pools have become more similar (Johnson and Hubbs 1989, p. 307) as there are fewer backcross hybrids than F1 hybrids suggesting that "backcrossed individuals may be at a selective disadvantage" (Edwards and Hubbs 1985, pp. 10-11).

During the 1960s and 1970s, Clear Creek gambusias were essentially restricted to the small upper headspring pool where it was abundant along the shallow, heavily vegetated margins. The upper dam impounding this pool was in disrepair, with water flowing through two breaches. Extensive hybridization with native western mosquitofish was centered above and below the breaches. Clear Creek gambusias were abundant in the upper pool, with western mosquitofish abundant in similar habitats in the adjacent lower pool (Hubbs 1959, p. 255).

In the upper pool, hybridization was attributed to winter migration of western mosquitofish through the dam breaches, a low level of intraspecies courtship preferences, and some overlap of activity peaks (Johnson and Hubbs 1989, p. 307). However, Peden (1975, p. 1295) showed that during gonopodial thrusts by male Clear Creek gambusia were directed posteriorly to match the posteriorly directed urogenital sinus (where sperm is inserted) of conspecific females, whereas those of western mosquitofish were reversed. This difference in morphology and behavior may limit, but apparently does not eliminate, hybridization.

The integrity of the earthen dam continued to deteriorate during the 1970s until it was repaired in 1978 (Edwards and Hubbs 1985, p. 5). It was predicted that repair of the dam would reduce hybridization frequency in the upper pool, thus preserving genetic integrity of the Clear Creek gambusia. Hybrid frequency had been about 10 percent in prior samples in the 1950s and 1960s (Hubbs 1971, p. 1), but following repair of the dam diminished to about 1 percent by 1984 (Edwards and Hubbs 1985, p. 6). Similarly, western mosquitofish abundance in the upper pool went from about 35 percent to below 10 percent during the same interval, in response to elimination of immigrant western mosquitofish (Edwards and Hubbs 1985, p. 7). Hybridization in the headspring pool above the first dam was barely detectable by 2003 (Davis et al. 2006, p. 357).

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms):

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

<u>Range</u>

The Clear Creek gambusia has an extremely limited range (Figure 1), with no known change since its discovery in the 1950s. It has never been known from more than the one isolated location in the headsprings area of Clear Creek within private land (Hubbs 1957, p. 8; Hubbs et al. 2008, p. 39). This narrow range in combination with a short life span significantly increases the probability of extinction from either known or unknown threats (Johnson and Hubbs 1989, p. 316) or stochastic (random) events (Melbourne and Hastings 2008, p. 100). One future event that negatively impacts this population could easily result in the complete loss of the species. Therefore, ongoing or future threats (described below) could potentially have an extremely high magnitude impact on the species.

<u>Threats to Habitat - Spring Flow</u>

The spring outflows from Wilkinson Spring and associated springs provide all the water for the habitat for the Clear Creek gambusia. Any substantial declines in the rate of flow from the springs would alter the habitat and could negatively affect the ecosystem that supports the Clear Creek gambusia population (Davis et al. 2004, p. 10). In the extreme case, if the flow from this spring ceased, then all of the species' habitat would be lost and the species would go extinct. Other springs in Texas have been impacted by loss of spring flow due to groundwater pumping (Anya and Jones 2009, pp. 48-49; TWDB 2006, p. 1-72) resulting in the elimination of the natural ecosystem and its fauna (for example, Comanche Springs and other springs near Fort Stockton, Hubbs 1990, p. 92; Scudday 1977, p. 516; Scudday 2003, pp. 136-137).

Water from the spring originates from the Edwards-Trinity (Plateau) Aquifer (Baker et al. 1965, p. 15; Brune 1975, p. 55). This is a major aquifer that extends over an area of about 35,000 square mi (90,000 km^2) beneath all or parts of 39 counties in Texas (Figure 3; Anaya and Jones 2009, p. 4).

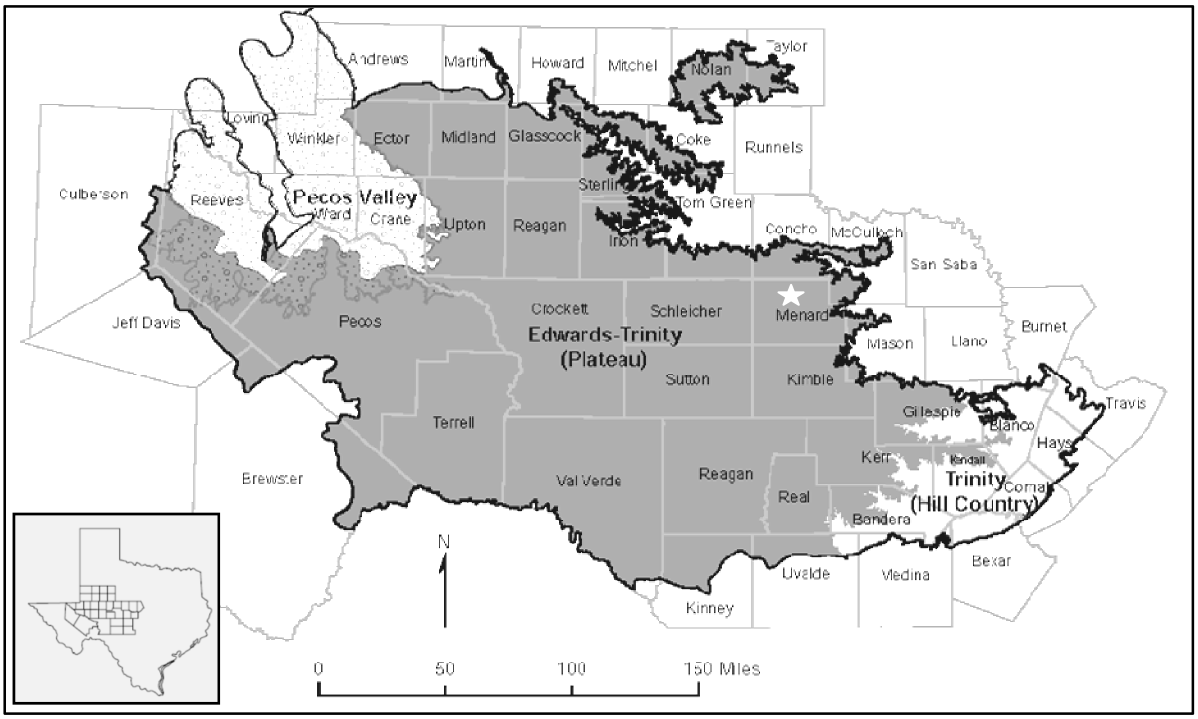

Figure 3. Edwards-Trinity (Plateau) Aquifer adapted map from Anaya and Jones (2009, p. 4). The white star shows the approximate location of Clear Creek in Menard County. Inset map of Texas shows the counties included in the Region F Water Planning Area (TWDB 2006, p. 1-2).

Clear Creek has almost no surface drainage area up-gradient of the headsprings (Wilkinson Spring) so all the water in the creek originates from spring flows. Periodic flow measurements of Clear Creek have been recorded over time downstream at the State Highway 190 Bridge crossing which is located about 2.8 mi (4.5 km) downstream of the headspring and about 0.3 mi (0.5 km) upstream of the confluence with the San Saba River

(Figure 1B). Figure 2 shows all of the discharge records available for the creek (Brune 1975, p. 55; USGS 2009). These flow records incorporate both the total spring flows from throughout the creek and intermittent runoff from the small surface drainage of the creek if measurements were taken following a rainstorm event. Since 1902, 99 discharge measurements have been made and the discharge has ranged from 6.2 cfs (0.18 cms) to 31.8 cfs (0.90 cms). The overall mean discharge is 16.2 cfs (0.46 cms) with a standard deviation of ± 4.7 cfs (± 0.13 cms).

The flow at Clear Creek has varied over the past 100 years, but the available data suggest it has never ceased to flow. Generally the drought during the early 1950s is considered the worst drought on record in Texas. Records reported by Brune (1975, p. 55) suggest the stream flows remained above 7 cfs (0.2 cms) even throughout this timeframe (Figure 2).

These flow data indicate that the historic and current spring flow levels have been and continue to be sufficient to maintain habitat for the Clear Creek gambusia. However, future spring flows could decline due to either increased human groundwater use within the contributing aquifer or reduced recharge rates because of reduced rainfall amounts over recharge areas from natural droughts, climate change, or other factors. The specific areas of recharge and the portion of the Edwards-Trinity (Plateau) Aquifer that contributes to the spring flows in Clear Creek have not been studied or defined (MCUWD 2005, p. 4), therefore it is difficult to know where groundwater conservation is most needed to ensure continued spring flows in Clear Creek.

To assess the threat of potential habitat loss from future spring flow declines, we evaluated the likelihood of significant increases in groundwater use of the Edwards-Trinity (Plateau) Aquifer (E-TP Aquifer) in areas north and west of Clear Creek in Menard and adjacent counties. Groundwater use in Menard County has historically been quite low because of limited high-producing wells and the use of surface water flows for most agriculture irrigation. Between 1990 and 1997, total groundwater use averaged 945 af (1.2 mcm) per year (Figure 4; MCUWD 2005, p. 4). This includes water use from all aquifers in the county, but most of the groundwater is from the E-TP Aquifer. Based on the historic flow rates in Clear Creek (Figure 2), we presume that, absent other changes in the hydrologic system, this current level of water use in Menard County is not likely to result in substantial decline in the spring flow rates. This is because it is a relatively small amount of water and the historical use of this amount of groundwater has not apparently impacted spring flows. Also, future water use in Menard County is not projected to rise significantly over the next 50 years (Figure 4) and the Menard County Underground Water District intends to protect future spring flows as part of its groundwater management plan (see discussion under section 2.3.2.4 below).

Groundwater in areas outside of Menard County could also influence spring flow rates in Clear Creek. The potential for new large groundwater wells being developed to draw water from the contributing aquifer that supplies the spring flow is a threat to the Clear Creek gambusia's habitat. However, since the specific geographic area of the E-TP Aquifer that contributes to flows in Clear Creek is not currently known, it is uncertain where this threat could ultimately occur. General groundwater flows in the county trend from the northwest to the southeast (Baker et al. 1965, p. 15). Therefore, neighboring areas, such as Schleicher and southern portions of Tom Green and Concho Counties (Figure 3), may contribute groundwater to Clear Creek and conservation there may be important for sustaining spring flows.

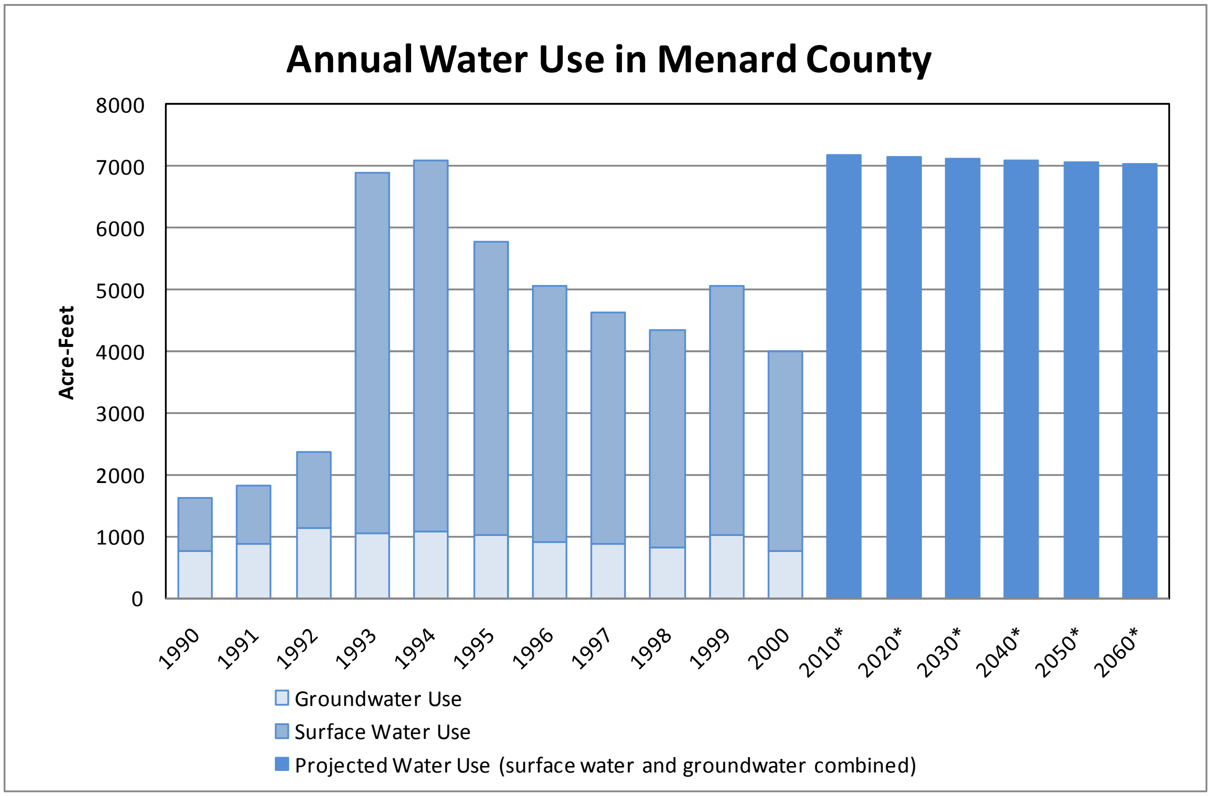

Figure 4. Recent and projected annual water use for Menard County. Actual water use is for years 1990 through 2000 (TWDB 2006, Table 1.2-2, p. 1-22) and annual projected water use (* 2010 – 2060) is by decade (TWDB 2006, Table 2.3-2, p. 2-8). Projected water use includes both groundwater and surface water. Groundwater totals are actual use data for all aquifers in Menard County (MCUWD 2005, p. 6).

Menard County and most of the E-TP Aquifer are located in the Texas Region F Water Planning Area. A 50-year water plan was completed for this region in 2006 (TWDB 2006). The water plan analyzes the available supplies compared with the likely future water demands of the region. One recognized need is for 30,000 af (37 mcm) of additional water for municipal use to accommodate population growth in the urban area of San Angelo in Tom Green County (TWDB 2006, Table 4.1-4). Tom Green County is located just northwest of Menard County (Figure 3).

The City of San Angelo has considered developing groundwater supplies from the E-TP Aquifer in the past (TWDB 2006, pp. 1-59, 4-210). The 2006 water plan suggests that over 62,000 af (76 mcm) of water per year is available from the E-TP Aquifer in Crockett, Schleicher, and Sutton counties. However, most of the water is contained in caverns or fractures in the Edwards limestone and this type of porosity tends to be highly localized, making it difficult to find areas with sufficient production for municipal supplies (TWDB 2006, p. 4-211). For this water planning cycle, strategies using the E-TP Aquifer were not included in the Region F recommendations for the City of San Angelo (TWDB 2006, p. 4-212). Therefore, groundwater pumping by the City of San Angelo does not appear to be an imminent threat to the Clear Creek gambusia's habitat at this time.

The City of Menard is also actively seeking a groundwater source to back up its current surface water supplies. Because water yields from the E-TP Aquifer tend to be low in Menard County, the city has been unsuccessful in locating an adequate supply from that source (TWDB 2006, p. 4-82) and is instead considering new wells in the Hickory Aquifer in the eastern portion of Menard County (TWDB 2006, p. 4-80). Therefore, groundwater pumping by the City of Menard does not appear to be an imminent threat to the Clear Creek gambusia's habitat at this time.

In addition to potential large-scale increases in groundwater withdrawals to meet regional water demands, there is also the potential for a slow increase in the number of small local wells developed close to the springs to serve individual homes and ranches. One of the concerns of the local government is the possibility of large agricultural ranches being subdivided into smaller tracts and sold and developed for recreational or domestic use (MCUWD 2005, p. 9). Many of these new residents would likely use groundwater sources for water supply and, over time, these wells could slowly add up to significant increases in groundwater use (MCUWD 2005, p. 9) that could affect the rate of spring flows. For additional discussion of the MCUWD, see section 2.3.2.4 below.

In conclusion, based on a low probability of increases in nearby groundwater use in the foreseeable future (water planning for 50 years), habitat threats from decreasing flows due to increasing groundwater withdrawals appear to be relatively low based on the best available information. Although not imminent, this threat will continue to exist because of the constantly increasing need for water to supply a growing human population in Texas (TWDB 2006, p. 2-2) and any changes in the spring flow rates could be devastating to the one isolated population of Clear Creek gambusia (Davis et al. 2004, p. 10).

Threats to Habitat - Water Quality

Maintaining clean water issuing from Wilkinson Spring is an important component of the ecosystem for Clear Creek gambusia habitat. Hubbs (2001, p. 311) documented the average water chemistry (and the coefficient of variation) of the spring outflow at Clear Creek based on 72 samples: temperature 20.85º C (0.04); dissolved oxygen 6.92 mg/L (0.24); turbidity 5.58 NTU (Nephelometric turbidity unit) (4.11); pH 7.09 (0.03); ammonia 0.28 mg/L (0.03); nitrates 12.62 mg/L (0.77); and salinity 0.29 parts per thousand (0.06).

Past concerns in the 1950s and 1960s regarding water quality in the area of Clear Creek involved the potential contamination of groundwater in Menard County from improper brine disposal during oil production. Most unlined earthen pits were in the county's northwestern part on the outcrop area of the Edwards and associated limestone. In many places this limestone is fractured and could allow for groundwater contamination (Baker et al. 1965, pp. 20-21). This is of particular concern in this area because water moves at a relatively fast rate through the Edwards and associated limestone of the E-TP Aquifer. Therefore, any potential contaminants entering the aquifer through the ground or a recharge feature may affect the quality of water in nearby wells or springs in a short time and the contaminants may move for long distances (Baker et al. 1965, p. 21). Future changes in land use in over the recharge zone could affect water quality. However, we are not aware of any water quality monitoring in Clear Creek that could verify that this situation has occurred in Clear Creek. So this threat is considered of low imminence at this time.

We are not aware of any other information indicating water quality problems that could threaten the Clear Creek gambusia, although our review found little information on this topic. The species occurs in a very rural part of Texas that does not experience the water quality problems associated with urban environments. Agricultural chemicals for pesticides or fertilizers could create water quality problems, but no specific water quality problems are known from Clear Creek. Therefore, threats to the species' habitat from water quality degradation are considered low at this time.

Threats to Habitat - Local Conditions

The natural habitat conditions in Clear Creek were altered significantly by the construction of the four dams. The upper dam that impounds the initial spring outflow where the Clear Creek gambusia now occurs may have been built as early as the 1880s and three other downstream dams were built after 1930 (Hubbs 1971, p. 1). The dams were used to divert water into irrigation canals to irrigate farm fields along the valley of Clear Creek, but had already been abandoned for irrigation by 1953 (Hubbs 1971, p. 1). In addition, this area of Texas was home to one of the earliest Spanish settlements as the San Saba Presidio (Spanish military fort) and Mission were occupied near Menard in the late 17th century (Brune 1975, p. 55), though it is unclear if the area around Clear Creek was inhabited at that time. Clear Creek was also inhabited by Native Americans before European settlement (Edwards and Hubbs 1985, p. 23).

The prior owners had the property for approximately a century (four generations of the Wilkinson family) before selling it to the current (as of 2010) owner in 1984. During the 1980s the banks of the large pool downstream of the upper dam were dredged to deepen the pool and remove the shallow water and cattails to improve recreational and aesthetic value of the creek. In addition, one of the downstream springs (“downstream spring” Figure 1B) where Clear Creek gambusia had been occasionally found, was modified and filled with gravel during construction of the nearby cabin. This reduced the flow of the spring (Hubbs 2001, p. 303) and altered the habitat conditions. These local changes may explain why Clear Creek gambusia were common at times along the shoreline areas of the lower pool in the early 1980s (Edwards and Hubbs 1985, pp. 8, 13-16), but virtually absent by the late 1990s (Hubbs 2001, pp. 317, 320-321; Davis et al. 2004, p. 16).

Because of the habitat modifications to the natural stream environment, the current upper dam is an important barrier that helps maintain stable spring habitat conditions, and it reduces the number of western mosquitofish that can compete and hybridize with Clear Creek gambusia (Davis et al. 2006, p. 358). In 2009, the integrity of the dam appeared to be significantly reduced due to erosion of the earthen and concrete structure. The majority of water now flows under the dam rather than through the gated drop structure (Allan 2009, p. 1). Presumably, as was the case from 1953 to 1978, the breaches in the dam are allowing western mosquitofish to again migrate into the upper pool during the winter. This may be increasing the percent of hybrids in the upper pool and reducing the relative abundance of pure Clear Creek gambusia (USFWS 1982, p. 5). This situation is even more important than in the past, as it seems that habitat changes in the spring outflow areas in the downstream pool have reduced or eliminated Clear Creek gambusia from that location (Hubbs 2001, p. 317).

The original recovery plan (USFWS 1982, p. 11) indicated that purchase of the property or negotiation of a conservation easement was the first priority recovery action for the Clear Creek gambusia. Investigations into purchasing the property in the early 1980s were unsuccessful. However, the current (2010) landowner has been cooperative and open to monitoring and conservation efforts for the Clear Creek gambusia. If the landowner changed or the property was subdivided for future developments, then local habitat conditions could be threatened by future habitat modification.

At this time the only foreseeable local threats to Clear Creek gambusia (barring change of ownership) is the deterioration of the upper dam that may be allowing the migration of western mosquitofish into the upper pool. The current situation presents a significant threat to the continued existence of the species.

2.3.2.2 Over-utilization for commercial, recreational, scientific, or educational purposes:

There is no evidence at this time that Clear Creek gambusia is threatened by overutilization. The only collections of the fish occur rarely for scientific purposes and are regulated by the USFWS pursuant to section 10(a)(1)(A) of the Act and by Texas Parks and Wildlife Department (TPWD, Title 31, Part 2, Chapter 69, subchapter J).

2.3.2.3 Disease or predation:

<u>Disease/parasites</u>

Little is known about disease or pathogens associated with the Clear Creek gambusia. It is possible that a disease or parasite could be introduced by other species moving into the area (such as birds or nutria) or inadvertently through human contact with the Clear Creek gambusia.

The most important animal vectors for fish diseases are birds. Several species of fish-eating birds carry life stages of parasites ("grubs") that infest fish. There is also some evidence that birds may be able to transmit bacteria or viruses through their droppings. Birds may also drop fish that they have removed from one body of water into another. We have no information available to assess the likelihood of this threat at this time, but future possible introductions of disease or parasites are a constant threat to this fish with a highly restricted range.

<u>Predation</u>

Predation does likely occur from the native predatory fish in Clear Creek (Hubbs 1971, p. 36), such as largemouth bass (*Micropterus salmonides*), green sunfish (*Lepomis cyanellus*), longear sunfish (*Lepomis megalotis*), redear sunfish (*Lepomis microlophus*), and yellow bullhead (*Ictalurus natalis*). Semi-aquatic snakes of the genus *Nerodia* and *Thamnophis* have also been documented to prey on Clear Creek gambusia (Hubbs 1971, p. 36). Avian predators like the belted kingfisher (*Megaceryle alcyon*), the great-blue heron (*Ardea herodias*), and the smaller green heron (*Butorides virescens*) all prey on small fishes in central Texas and could eat Clear Creek gambusia. Predation from these species is considered natural because these predators are native species and this threat alone is not considered substantial. However, as other threats occur, such as past and future habitat alteration, predation could be a confounding threat to the species, increasing the probability of extinction.

2.3.2.4 Inadequacy of existing regulatory mechanisms:
Regulatory mechanisms, beyond those imposed by the Act, that are important for conservation of the Clear Creek gambusia, include protections of the fish by the TPWD and groundwater regulation by the Menard County Underground Water District.

<u>State listing</u>
The State of Texas lists the Clear Creek gambusia as endangered under Title 31 Part 2 of Texas Administrative Code. TPWD regulations prohibit the taking, possession, transportation, or sale of any animal species designated by State law as endangered or threatened without the issuance of a permit. There is no protection by State law for habitat or minimum stream or springs flows for State-listed species, therefore, only minimal protections are afforded the Clear Creek gambusia by the State of Texas and these protections do not address threats to the species.

<u>Groundwater management</u>
In Texas, groundwater is generally managed through local groundwater conservation districts. The Menard County Underground Water District (District) was approved in 1999. The District is governed by five, locally elected board of directors.

The mission of the District is to: "develop, promote and implement water conservation and management strategies a) to conserve, preserve, and protect the surface and groundwater supplies of the District, b) to protect and enhance recharge, prevent waste and pollution, c) to effect efficient use of groundwater within the District, and d) to protect the owners of water rights within the District from impairment of their groundwater quality and quantity" (MCUWD 2005, p. 1).

The guiding principles of the District include: "Preventing depletion of the aquifers underlying the District to protect spring flows and assure an adequate supply of water for future municipal, domestic, agricultural and commercial use" (MCUWD 2005, p. 1).

The management plan also states, "In order to maintain dependable and sufficient groundwater supplies for future generations, the District has as its goal zero percent depletion of the Edwards-Trinity aquifer. Until better data is [sic] available, this goal of sustainability will be implemented by limiting annual production within the aquifer to estimated annual drought recharge" (MCUWD 2005, p. 7).

The District management plan indicates that the estimated annual drought recharge to the Edwards-Trinity (Plateau) Aquifer in Menard County, and therefore the amount of groundwater available for use, is 15,357 af (18.9 mcm) per year (MCUWD 2005, p. 7). If this amount of groundwater were actually withdrawn from Menard County it would represent an increase of 15 times more than the recent recorded groundwater use of less than 1,000 af (1.2 mcm) of water (MCUWD 2005, p. 6). Depending on where future wells were located to extract this amount of groundwater, it could result in lower spring flows in Clear Creek. However, the projections for total water demand in Menard County are not expected to actually increase over the next 50 years (Figure 4), according to the Region F Regional Water Plan (TWDB 2006, Table 2.3-2, p. 2-8) and the MCUWD management plan (MCUWD 2005, p. 9).

Protecting spring flows is important to Menard County citizens because the majority of water use in the county is from surface water flows in the San Saba River. In all, 8,935 af (11.0 mcm) of surface water rights exist for irrigation and 1,016 af (1.25 mcm) for municipal use by the City of Menard (MCUWD 2005, p. 5). This is compared with a total groundwater use in the county of around 1,000 af (1.2 mcm) annually (Figure 4). Flows in the San Saba River originate as spring discharges in the western portions of the county (Baker et al. 1965, p. 15; MCUWD 2005, p. 5). A substantial portion of this flow is provided by the outflow of the springs on Clear Creek. For example, the mean discharge from Clear Creek of 16.2 cfs (0.46 cms), ± 4.7 cfs (± 0.13 cms), represents an average surface flow of over 11,000 af (over 14 mcm) (± 3,400 af, ± 4 mcm) of water per year that Clear Creek contributes to the surface flow of the San Saba River. This is more than the total amount of water used annually in Menard County. Although the District is aware of the Clear Creek gambusia location and its need for conservation, there are no regulatory authorities that specifically protect habitat (such as necessary flows or water quality) in Clear Creek for the Clear Creek gambusia.

Since 1996, the District has worked with 10 other groundwater districts as part of the West Texas Regional Groundwater Alliance. These 11 districts coordinate and implement common objectives of facilitating the conservation, preservation, and beneficial use of water resources through exchange of information and policy discussions (MCUWD 2005, p. 3). Although the organization does not have shared regulatory authority, the cooperation is important as the groundwater in the E-TP Aquifer crosses a number of groundwater districts. Groundwater conservation and management outside of Menard County may be important to maintain the spring flows in Clear Creek.

Other

Other regulations that could provide some general habitat protections for Clear Creek include section 404 of the Clean Water Act (regulation of dredge and fill of the waters of the U.S.) implemented by the U.S. Army Corps of Engineers, and programs for water quality protections implemented by the Texas Commission on Environmental Quality. However, because the Clear Creek gambusia occurs in a remote rural setting there are few, if any, actions occurring that fall within the regulated activities of these programs.

Summary

The imminence of the threats to Clear Creek gambusia from the lack of regulatory mechanisms is considered moderate at this time because the species occurs on private property (providing some protection by preventing access by the public) and the habitat conditions related to spring flow rates and water quality are not presently considered highly threatened with change. The District possesses the regulatory structure to provide some important protections for spring flows in Clear Creek if the District rules are closely tied to spring flows and enforced in the future.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

Hybridization

Whole populations of fish species can be quickly lost due to hybridization with an introduced, nonnative, related species (for examples, see Pecos pupfish in the Pecos River, Echelle and Connor 1989, p. 725-726; Leon Springs pupfish in Diamond Y Spring, Echelle and Echelle 1997, pp. 159-160). The case with Clear Creek gambusia is unique in that hybrids are occurring with the closely related native species, the western mosquitofish. The presumption by biologists is that this situation has occurred because of the extensive habitat modification (dams) that brought the stenothermal (narrow range of temperatures) spring outflow habitat into abrupt contact with the eurythermal (wide range of temperatures) waters of the impoundment pool (Hubbs 1971, pp. 38-39; Johnson and Hubbs 1989, p. 308).

A similar situation has already led to the presumed extinction of one similar species in Texas. The San Marcos gambusia (*Gambusia georgei*) is believed to be extinct (Edwards 1999, p. 3) following habitat modifications in the San Marcos Spring system and ultimately from hybridization with the native western mosquitofish (USFWS 1996, pp. 29-30).

The hybrid swarm between Clear Creek gambusia and western mosquitofish persisted in the upper pool from the initial discovery in 1953 until the upper dam was repaired in 1978. The dam repair reduced the ability of the western mosquitofish to move upstream past the dam during the winter and reduced the level of contact between the two species (Edwards and Hubbs 1985, p. 13). The level of hybridization dropped from 10 percent before the dam repair to 1 percent after the dam repair (Edwards and Hubbs 1985, p. 6; Johnson and Hubbs 1989, p. 308). This level of hybridization was apparently maintained through at least January 2003, when Davis et al. (2006, p. 352) collected gambusia from habitats upstream and downstream of the upper dam on Clear Creek. Prior analyses had relied on an index based on extensive morphological measurements to evaluate the extent of hybridization (Hubbs 1959, pp. 236-239; Hubbs 1971, pp. 13-18; Edwards and Hubbs 1985, p. 6), but Davis et al. (2006, p. 352-353) included modern DNA techniques to assess the extent of hybridization. The resulting analyses of microsatellite genomic DNA, mitochondrial DNA, and the morphological index of the fish collected in 2003 all suggested very low levels of hybridization (less than 1 percent) and a very low degree of backcrossing (Davis 2006, pp. 357-358).

The evidence for ongoing introgression in 2003 between western mosquitofish and Clear Creek gambusia was weak (Davis et al. 2006, p. 351), which is consistent with past conclusions that suggested isolating mechanisms reduce the likelihood of backcross hybrids (Hubbs 1971, p. 38-39; Edwards and Hubbs 1985, p. 10-11). The available genetic data also suggest “severe post-mating isolation” prevents long-term introgression of the gene pool (Davis et al. 2006, p. 358). In other words, it appears that first generation (or F1) hybrid fish are not successfully mating and reproducing and, therefore, are neither replacing nor genetically swamping either species of Clear Creek gambusia or western mosquitofish. Hubbs (1971, p. 43) summarized it this way: “Despite the presence of abundant hybrids for more than one decade, each species has maintained its distinct morphology, showing that each is a distinct and integrated gene pool. The factors influencing genetic divergence are at least as great as those which might cause genetic fusion.”

The synthesis of the genetic work in 2003 determined that, “from the standpoint of conservation there seems to be little need for concern regarding the genetic integrity of the wild population of *G. heterochir*” (Davis et al. 2006, p. 357). However, the study also concluded that this situation could change if the spring flows declined or if the dam were not maintained in a way that serves to separate the western mosquitofish downstream from the Clear Creek gambusia in the upper pool (Davis et al. 2006, pp. 357-358). Since the analysis of the fish in 2003, the upper dam has again deteriorated (Allan 2009, p. 1) and the levels of hybridization may now be higher as a result. This heightens the potential likelihood of this threat negatively affecting the population of Clear Creek gambusia. The level of hybridization in the upper pool has not been assessed since 2003.

Competition

Competition for resources of food and space likely occur in the upper spring pool between Clear Creek gambusia and western mosquitofish (Hubbs 1971, p. 26). Both fish eat primarily insects and amphipods, with Clear Creek gambusia diet favoring amphipods and western mosquitofish diet favoring insects. This distinction is greatest during warmer months. During the winter however, western mosquitofish also consumed more amphipods and were in the greatest abundance in the upper pool when the dam did not prevent their migration (Hubbs 1971, p. 26). The relative percentage of western mosquitofish (compared to all gambusia collected) in the upper pool declined from about 35 percent to about 10 percent following repair of the upper dam in 1978 (Johnson and Hubbs, 1989 p. 308). Hubbs (2001, p. 317) later reported continuing similarly low relative abundances of western mosquitofish.

If western mosquitofish have easy access to migrate past the upper dam in the winter, they likely compete with Clear Creek gambusia for food and space resources, causing lower population numbers of Clear Creek gambusia due to overwinter starvation (Hubbs 1971, p. 26) and increasing the probability of extinction of the remaining small population of Clear Creek gambusia in the upper pool. The upper dam has again deteriorated in recent years and is likely now allowing access to the upper pool by western mosquitofish where its relative abundance has not been quantified since the late 1990s.

Nonnative species

Nonnative species are not known to pose any substantial threats to the Clear Creek gambusia, but we review two nonnative species that are known to be present at Clear Creek and that could be of concern. If other nonnative species were to be introduced to Clear Creek, they could impact the species.

Nutria (*Myocastor coypus*) is an aquatic, invasive mammal species that has had impacts on the integrity of the upper dam in the past by burrowing into the earthen structure. They were also noted to have decimated emergent and riparian vegetation along the creek in the 1950s (Hubbs 1971, p. 1). Nutria continue to occur in the area and could continue to be problematic for maintaining the upper dam, as they are a burrowing mammal that digs dens at the water level. This would allow immigration by western mosquitofish and have negative impacts on Clear Creek gambusia (see sections 2.3.2.5, Hybridization and Competition above). Nutria can also be a vector for disease transference (Drake 2005, p. 15).

Rainwater killifish (*Lucania parva*) was discovered in Clear Creek in the early 1980s (Edwards and Hubbs 1985, p. 15). The fish is native to the Gulf Coast of Texas and was presumably introduced from a bait bucket release. They are members of a related family (Fundulidae), but are reproductively isolated from poeciliids (Edwards and Hubbs 1985, p. 16). It has only been found in Clear Creek downstream of the upper dam. It was initially quite abundant, apparently competing with western mosquitofish and allowing the relative abundance of Clear Creek gambusia to increase in habitats below the upper dam in the early 1980s (Edwards and Hubbs 1985, pp. 13-16). By the 1990s, Hubbs (2001, p. 318) reported only a small percentage of rainwater killifish in Clear Creek, however, most sampling for this study was done upstream of the upper dam. Rainwater killifish does not appear to threaten Clear Creek gambusia, but it is unknown if it would present a problem if it became established in the upper pool. Fish sampling in recent years has been insufficient to determine if the current breaches in the upper dam have allowed this species to move into the upper pool.

Climate change

According to the Intergovernmental Panel on Climate Change (IPCC 2007, p. 1), "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." Average Northern Hemisphere temperatures during the second half of the 20th century were very likely higher than during any other 50-year period in the last 500 years and likely the highest in at least the past 1,300 years (IPCC 2007, p. 1). It is very likely that over the past 50 years cold days, cold nights, and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent (IPCC 2007, p. 1). Data suggest that heat waves are occurring more often over most land areas, and the frequency of heavy precipitation events has increased over most areas (IPCC 2007, p. 1).

The IPCC (2007, pp. 6-7) predicts that changes in the global climate system during the 21st century are very likely to be larger than those observed during the 20th century. For the next two decades a warming of about 0.2 °C (0.4 °F) per decade is projected (IPCC 2007, p. 6). Afterwards, temperature projections increasingly depend on specific emission scenarios (IPCC 2007, p. 6). Various emission scenarios suggest that by the end of the 21st century, average global temperatures are expected to increase 0.6 °C to 4.0 °C (1.1 °F to 7.2 °F) with the greatest warming expected over land (IPCC 2007, pp. 6-8).

Localized projections suggest the southwest U.S. may experience the greatest temperature increase of any area in the lower 48 states (IPCC 2007, p. 8), with warming increases in southwestern states greatest in the summer. The IPCC also predicts hot extremes, heat waves, and heavy precipitation will increase in frequency (IPCC 2007, p. 8). Karl et al. (2009, p. 12) suggest that warming of the U.S. climate is already happening and is increasing. Large climate change impacts on water resources in the southern Great Plains are expected as rising temperatures and decreasing precipitation exacerbate an area already plagued by low rainfall, high temperatures, and unsustainable water use practices (Karl et al. 2009, p. 126).

Modeling efforts evaluating climate change in the central region of Texas have only recently been initiated (Jackson 2008; Mace and Wade 2008). As with many areas of North America, this area (central and western Texas) is projected to experience an overall warming trend in the range of 2.5 to 3.9 ºC (4.5 to 6 ºF) over the next 50 to 200 years (IPCC 2007, p. 9; Mace and Wade 2008, p. 656). There is also high confidence that many semi-arid areas like the western U.S. will suffer a decrease in water resources due to climate change (IPCC 2007, p. 7), as a result of less annual mean precipitation and reduced length of snow season and snow depth. Milly et al. (2005, p. 347) also project a 10 to 30 percent decrease in precipitation in mid-latitude western North America by the year 2050 based on an ensemble of 12 climate models. Even under lower emission scenarios, recent projections forecast a 5º F increase in temperature and a 10 percent decline in precipitation in this central Texas by 2080-2099 (Karl et al. 2009, pp. 123, 124).

Although local precipitation models vary substantially, with some even predicting increased annual precipitation, a consensus is emerging that evaporation rates in central and western Texas are likely to increase significantly (Jackson 2008, p. 21). Many models are also predicting that seasonal variability in flow rates is likely to increase with more precipitation occurring in the wet seasons and more extended dry periods and result in overall higher evaporation rates from increased temperatures and dry winds (Jackson 2008, p. 19; Mace and Wade 2008, p. 656).

Expected future warming from climate change could decrease overall availability of water recharging to aquifers in central and western Texas. If this were to occur, spring flows could decline directly because of decreases in recharge from declining precipitation, because the aquifer is dependent on rainfall precipitation for recharge (Anya and Jones 2009, p. 47). The normal annual rainfall for Menard County is about 22 in (56 cm) and any changes in precipitation will affect groundwater available to support spring flows. Mace and Wade (2008, p. 659) also expected the Edwards-Trinity (Plateau) Aquifer to be susceptible directly to climate change because the karstic nature (porous rocks) of the aquifers provides quick recharge from precipitation events.

Indirectly, any declines in precipitation or increases in evaporation rates from climate change could result in increases in groundwater pumpage. Climate has a significant effect on the amount of groundwater pumpage from the Edwards-Trinity (Plateau) Aquifer because of increased irrigation pumpage during drought times (Anaya and Jones 2009, p. 48). Mace and Wade (2008, p. 664) also concluded that increasing pumping rates may be one of the indirect effects of climate change on aquifers in Texas.

Other potential effects of climate change on the physical and biological environment of the Clear Creek gambusia are possible, but difficult to predict as no formal vulnerability assessment has been completed. The Clear Creek gambusia may be highly sensitive to the effects of climate change because its habitat is closely dependent on stable flows (from precipitation) and water temperatures. Any change in water temperature variation in spring outflows could be a serious concern to the fish because it appears to be closely dependent on water with low temperature variability. The spring habitat of the fish is dependent on groundwater levels that are directly influenced by precipitation patterns which could be altered as a result of climate change. Therefore, the amount of exposure to the potential effects of climate change would be high.

Other indirect climate change effects to water quality, nonnative species, disease susceptibility, or other factors are possible. We lack sufficient certainty to know how climate change may specifically affect this species. However, because of the extremely small range and dependence on specific environmental conditions, any potential changes to its environment could result in the extinction of the species.

The Clear Creek gambusia also has no opportunity to migrate and it is unlikely it could be successfully relocated to alternate environments. Therefore, its capability to adapt to environmental changes from climate change is presumed low. Therefore, although the imminence of the threats related to climate change can be considered low, the magnitude of effects of those changes on the Clear Creek gambusia is considered high.

Small Population Size and Stochastic Events

The Clear Creek gambusia may be susceptible to threats associated with small population size and impacts from stochastic events. The risk of extinction for any species is known to be highly indirectly correlated with population size (Ogrady et al. 2004, pp. 516, 518; Pimm et al. 1988, pp.

774-775). In other words, the smaller the population the greater the overall risk of extinction. True population size estimates have not been generated for this species, but the small area of suitable habitat in the spring pool severely limits the number of individuals. Small population sizes can also act synergistically with other traits (such as a habitat specialist and limited distribution as in the Clear Creek gambusia) to greatly increase risk of extinction (Davies et al. 2004, p. 270). Stochastic events from either environmental factors (random events such as severe weather) or demographic factors (random causes of births and deaths of individuals) are also heightened threats to the Clear Creek gambusia because of the limited range and small population sizes (Melbourne and Hastings 2008, p. 100). Finally, the small range of only one population of this fish does not provide any opportunity for natural recolonization if any of these factors resulted in a local extirpation event (Fagan et al. 2002, p. 3255).

2.4 Recent Conservation Actions

Listed below are some conservation actions that have occurred since the completion of the recovery plan in 1982.

2.4.1 Rio Grande Fishes Recovery Team

The Rio Grande Fishes Recovery Team (RGFRT) has continued to make recommendations to the USFWS regarding recovery implementation for the Clear Creek gambusia (for example, RGFRT 2009, p. 4). The RGFRT meets routinely (about annually) to discuss conservation needs of threatened and endangered fishes in western Texas and southeastern New Mexico. This voluntary team has been serving continually since 1978 (USFWS 2009, p. 1).

2.4.2 Monitoring by Dr. Clark Hubbs:

The late Dr. Clark Hubbs (deceased in 2008), RGFRT Team Leader from 1978 until his death and Professor at the University of Texas at Austin since 1948, periodically monitored the Clear Creek gambusia from the time of discovery in 1953 through 2007. Water chemistry and population data for Clear Creek collected during the 1990s were published in Hubbs (2001, pp. 303-304, 309, 311, 313, 317-321). Much of this work was supported by funding from the Texas Water Development Board. Throughout the 2000s, Dr. Hubbs continued to make regular trips to Clear Creek to collect water chemistry and fish population information. Much of these data were not published, but provided some assurance through communications with the RGFRT that the fish populations were persisting. Dr. Hubbs was an ardent advocate for both scientific discovery related to Clear Creek gambusia and for its conservation. Dr. Hubbs also maintained a strong relationship with the landowners, providing a vital foundation of cooperation for the benefit of this rare fish and its unique habitat.

2.4.3 Updated status of hybridization:

In 2003, Dr. Tony Echelle, Oklahoma State University, used genetic analysis to update the status of the hybrid swarm in Clear Creek and provide a genetic baseline by which to establish a future captive stock. The hybrid swarm had not been evaluated since the early 1980s (Edwards and Hubbs 1985). The resulting data were published in Davis et al. (2004, 2006) and established that the level of hybridization at that time was very low, as less than 1 percent (1 fish out of 118) were possible hybrids. The project was funded in 2002 with discretionary Recovery Program funds from the USFWS's Austin ESFO.

2.4.4 *Preventing Extinction* projects:

In Fiscal Years 2008 and 2009 the USFWS's Fisheries Program led an effort to request special funds through the USFWS's Showing Success/Preventing Extinction Initiative to prevent the extinction of the Clear Creek gambusia. In 2008 funds were provided to initiate a captive stock of the fish at Inks Dam National Fish Hatchery (see section 4.2 below) and in 2009 funds were provided to initiate repair of the upper dam and establish a monitoring program (see sections 4.3, 4.4, and 4.5 below). As of early 2010, the necessary facilities to hold the fish at Inks Dam NFH have been completed, a captive management plan has been drafted, and plans are in place to bring the species into captivity in 2010. Plans for repairing the upper dam were initiated in 2009 and are proceeding in 2010 with additional funding possible from the USFWS's Partners for Fish and Wildlife Program.

2.5 Synthesis

The best available information indicates that the primary threats to the Clear Creek gambusia are: 1) habitat loss from the potential loss of spring flow due to a decline in groundwater levels, and 2) hybridization or competition with western mosquitofish initially due to the local habitat modifications, but now caused by the failure of the upper dam to maintain a barrier between spring outflow and downstream habitats.

The information reviewed does not indicate that impacts to spring flows from significant increase in groundwater use or declines in recharge is imminent (defined here as likely to occur in the next 10 years) at this time. However, it is likely to occur over the foreseeable future of 50 to 100 years as a result of climate change and the increasing human need for more water resources. The magnitude of impact on the Clear Creek gambusia if this threat were realized is extremely high. Because the range of the species is limited to one small, isolated location, habitat modification due to a decline in spring flows could result in its extinction.

The threats associated with hybridization and competition may be occurring now due to the recent erosion of the upper dam allowing renewed access to the upper spring pool by western mosquitofish. If the impacts of these threats are the same as observed in the past between 1953 and 1978, then the population of Clear

Creek gambusia will be depressed, but not eradicated until the upper dam can be repaired. Therefore, the magnitude of the impact of this threat on the species is considered moderate to high.

Secondary threats include habitat modification from water quality degradation, local habitat changes, lack of regulatory mechanisms, and introduction of a disease, parasite, or nonnative species (resulting in competition or predation). None of these concerns acting alone result in substantial threats to the species, but together any of these could negatively impact the Clear Creek gambusia.

Climate change is another source of potential threats to the species. All possible impacts associated with future climate change cannot presently be reliably predicted. However, accelerating climate change will exacerbate any of the threats already considered or could result in whole new threats that are not conceived at this time. Either way, subtle but significant changes in the ecosystem of the Clear Creek gambusia resulting from climate change in the foreseeable future of 50 to 100 years could cause the species extinction and is a threat of high magnitude.

All of these threats, both primary and secondary, must be considered in the context of a fish with an extremely small range with no opportunity for movement, a relatively small population size, and a very short life span. Because of these factors, the magnitude of impact of any potential threat or future stochastic event is exceptionally high. Any events negatively affecting the species or its habitat could result in complete extinction of the Clear Creek gambusia. Therefore, we recommend that the Clear Greek gambusia remain classified as endangered.

3.0 RESULTS

3.1 Recommended Classification

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
 ____ *Extinction*
 ____ *Recovery*
 ____ *Original data for classification in error*
__X__ **No change is needed**

3.2 New Recovery Priority Number:

No change; remain as 2.

Brief Rationale:
Threats are sufficiently high in magnitude and imminence to warrant a recovery priority of 2. Threats from spring flow loss and hybridization and competition in

the context of only one small population places the Clear Creek gambusia at a very high risk of extinction.

3.3 Listing and Reclassification Priority Number: N/A

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The following recommendations are provided to direct actions in the coming years to further the recovery of the Clear Creek gambusia. They are generally listed in priority order. They are based on the species recovery plan (USFWS 1982) and recent considerations by the Rio Grande Fishes Recovery Team (RGFRT 2009, p. 4), TPWD, the landowner at Clear Creek, and the USFWS. The recommended actions are to:

1) Maintain a positive relationship with the landowner,
2) Establish a captive stock,
3) Repair the upper dam,
4) Monitor fish populations,
5) Monitor water quality and spring discharge,
6) Cooperate with the Menard County Underground Water District,
7) Conduct climate change vulnerability analysis, and
8) Update the recovery plan.

4.1 Maintain a positive relationship with the landowner.

The current landowner has been a cooperative partner for conservation of the Clear Creek gambusia by generously granting access to biologists in the past. Maintaining a positive, collaborative relationship with the private landowner (and any future landowner) is paramount in conserving the Clear Creek gambusia, as with all conservation issues on private lands in Texas (Garrett 2003, p. 159). Personnel from the TPWD and the USFWS have had renewed positive contact with the landowner in 2009. The current landowner is open to assisting implementation of the conservation actions listed below. This task (4.1) should be ongoing.

4.2 Establish a captive stock.

The Clear Creek gambusia has never been in captivity other than in laboratory aquaria for research purposes. It is important to maintain a captive stock so that if a catastrophic event occurred that resulted in the loss of the wild population, a backup stock could be used to restore the species to the wild and prevent its extinction (Davis et al. 2004, pp. 11-12). A Genetic Reserve Population and Stock Management Plan is currently being drafted by the Dexter National Fish Hatchery and Technology Center in cooperation with Inks Dam National Fish Hatchery to direct the activities of establishing and maintaining a captive stock at Inks Dam National Fish Hatchery. The document will provide specific guidelines to preserve genetic identity, diversity, and viability for the population and ensure the program is in compliance with the USFWS's 2000 Policy Regarding Controlled Propagation (65 FR 56916). Funds were provided to the USFWS's Fisheries Program for this task through the USFWS's Preventing Extinction Initiative in FY2008. This task should be accomplished in 2010 and should continue until no longer necessary. [Recovery Task 1.32 (USFWS 1982, p. 16)]

4.3 Repair the upper dam.

The small dam that maintains the upper pool and contains the majority of the Clear Creek gambusia is no longer functioning as an effective barrier to the western mosquitofish due to erosion. Water is now flowing through the dam. This condition likely allows the western mosquitofish to migrate through the dam in the winter and compete and hybridize with Clear Creek gambusia. The integrity of the upper pool dam should be restored to prevent the movement of western mosquitofish into the upper pool (Davis et al. 2006, p. 358) and maintain the stenothermal conditions there. Funds were provided to the USFWS's Fisheries Program to begin this task through the USFWS's Preventing Extinction Initiative in FY2009. This task is being initiated in 2010 and will be completed as soon as possible. [Recovery Tasks 1.4 (USFWS 1982, p. 16)]

4.4 Monitor fish populations.

Regular, routine monitoring of the Clear Creek gambusia population (including periodic genetic analysis to assess the status of hybrids) in the upper pool should be carried out. The purpose is to establish a quantifiable baseline status of the species sufficient to document future trends in the population. Monitoring should include relative abundance of Clear Creek gambusia compared to western mosquitofish, proportion of hybrid fish based on genetic sampling, and presence of other fish species. Funds were provided to the USFWS's Fisheries Program for this task through the USFWS's Preventing Extinction initiative in FY2009. This task will be initiated in 2010 by staff from the San Marcos National Fish Hatchery and Technology Center and should be ongoing. [Recovery Task 1.311 (USFWS 1982, p. 15)]

4.5 Monitor water quality and spring discharge.

Water quality monitoring should be undertaken for the spring outflow into the upper headspring pool to obtain current water quality data (such as temperature, pH, dissolved oxygen, and salinity). Funds were provided to the USFWS's Fisheries Program for this task through the USFWS's Preventing Extinction initiative in FY2009. This task will be initiated in 2010 by staff from Inks Dam National Fish Hatchery and should be ongoing.

Spring flow rates are only monitored by periodically measuring the stream discharge in Clear Creek at the highway crossing downstream. These data measure the aggregate flow of the creek, as there are likely other spring sources downstream for the headspring where the Clear Creek gambusia occurs. However, measuring only the discharge of Wilkinson Spring would be ideal but difficult to implement and probably not necessary. Measuring the creek flow should provide a reliable measure of the spring outflow. The USFWS should work with the USGS and Menard County UWD to determine if the flow at Clear Creek can be measured more frequently or, ideally, if a continuous gage could be installed. [Recovery Tasks 4.1 (USFWS 1982, p. 16)]

4.6 Cooperate with Menard County UWD.
The USFWS and TPWD should cooperate with the Menard County Underground Water District (District) to assist the District in making protection of spring flows from Clear Creek a high conservation priority. Information and plans should be exchanged and communications remain open. A common need in this area is for geologic and hydrologic studies to define recharge areas of groundwater in the county and groundwater movement into and through the county as it relates to Wilkinson Spring. The USFWS and TPWD should work with the USGS and Texas Water Development Board to look for opportunities to support these studies so that the District, and neighboring groundwater districts, can obtain the information needed to manage the aquifer resources to sustain spring flows from Clear Creek. [Recovery Tasks 4.1 (USFWS 1982, p. 16)]

4.7 Conduct climate change vulnerability analysis.
Studies should be initiated to evaluate the vulnerability of Clear Creek gambusia to the future impacts associated with climate change. For example, direct studies should be undertaken to determine thermal preferences and tolerances and effects of temperature on life history parameters that influence the Clear Creek gambusia's population dynamics. Studies should consider the effects of accelerating climate change on future groundwater levels and water temperatures at the spring outlets.

4.8 Update the recovery plan.
The recovery plan should be updated to include objective and measurable criteria that take into consideration all of the threats to the species, including climate change. This is currently considered the lowest priority action because other conservation actions described in this 5-year review should be conducted first to accomplish tangible benefits for conservation of the species.

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6.0 SIGNATURE PAGE

U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW of Clear Creek gambusia, *Gambusia heterochir*

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: N/A

Review Conducted By: Nathan Allan, Austin ESFO

FIELD OFFICE APPROVAL:

Lead Field Supervisor, U.S. Fish and Wildlife Service, Austin ESFO

Approve [signature] Date March 4, 2010

REGIONAL OFFICE APPROVAL:

Acting **Assistant Regional Director, Ecological Services, U.S. Fish and Wildlife Service, Region 2**

Approve Elizabeth [signature] Date 5/7/10